How Elementary is Diversification? A Study of Children's Portfolio Choice*

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Abstract

Diversification is a fundamental concept in economics, decision theory, and finance. This paper asks how elementary the notion of diversification is by studying whether children apply it as a choice heuristic. We find that children do exhibit preferences for diversification, both for the sake of variety across consumption goods and for the purpose of mitigating risk when faced with a choice across risky gambles. Our results indicate that diversification preferences may have fundamental, developmental roots, which contrasts with the traditional normative view of diversification, in which most economic models take diversification preferences as exogenously given. This may have implications for how one can treat investment anomalies in practice and, in particular, supports financial literacy training from a young age.

Keywords: diversification, portfolio choice, risk aversion, children's decision making
JEL Classification: C91, D91, G11

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Diversification is a fundamental concept in economics, decision theory, and finance. This paper asks how elementary the notion of diversification is by studying whether children apply it as a choice heuristic. We find that children do exhibit preferences for diversification, both for the sake of variety across consumption goods and for the purpose of mitigating risk when faced with a choice across risky gambles. Our results indicate that diversification preferences may have fundamental, developmental roots, which contrasts with the traditional normative view of diversification, in which most economic models take diversification preferences as exogenously given. This may have implications for how one can treat investment anomalies in practice and, in particular, supports financial literacy training from a young age.

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1 Introduction

Diversification is a fundamental concept in a wide variety of fields, such as financial economics, decision theory, sociology, consumer theory, economic growth, genetics and evolution. From a broad perspective, it conveys the idea of introducing variety to a set of objects by not putting all of one's proverbial eggs into one basket. This is a paradigm which goes as far back as the Talmud (ca. 200 CE), which states that "*it is advisable for one that he should divide his money in three parts, one of which he shall invest in real estate, one of which in business, and the third part to remain always in his hands.*" In an economic context, Bernoulli (1738) may have been the first to formally argue for the benefits of diversification. In his fundamental 1738 article on the St. Petersburg paradox, Bernoulli (1738) argues by example that risk averse investors will want to diversify: *"Another rule which may prove useful can be derived from our theory. This is the rule that it is advisable to divide goods which are exposed to some danger into several portions rather than to risk them all together.*" But perhaps the most prominent conceptual theory of diversification is that of Darwin (1859), who introduced the idea that a greater diversity of life forms is conducive to a greater level of functioning and higher evolutionary fitness level.

Today, there is general consensus that some form of diversification is beneficial in an array of seemingly disparate contexts: variety-seeking is typical of consumer behavior, diversity improves growth, innovation, and competition, and diversified choices provide a buffer against future uncertainty. Moreover, desirability for diversification is a cornerstone of a broad range of decision making and portfolio choice models in economics and finance, lead by the seminal works of von Neumann and Morgenstern (1944) and Markowitz (1952). However, the views of what constitutes diversification in decision making in general and in portfolio choice in particular differ substantially, and the way in which diversification is interpreted and implemented in the real world varies greatly. Indeed, there is an ongoing debate about what the "best" level of diversification should be. There is also a recent trend of evaluating certain diversifying heuristics as being "anomalous" and "irrational" behavior. It is documented that even Harry Markowitz used the simple $1/n$ naive diversification heuristic when he made his own retirement investments. He justifies his choice on psychological grounds: "*My intention was to minimize my future regret. So I split my contributions fifty-fifty between bonds and equities.*" (Gigerenzer 2010)

The purpose of this paper is to initiate and contribute to the discussion of the foundations of diversification preferences. We ask how elementary the notion of diversification is by studying whether children apply it as a choice heuristic in a sequence of games replicating simple portfolio choice problems. If children exhibit an intrinsic preference for diversification, we also investigate the particular form of diversification they apply and whether there is a relationship between risk aversion and preference for diversification.

There are numerous reasons to study the mechanisms that underlie decision making in humans: to make better predictions about how people will act in the real world, to generate new hypotheses about the factors that lead to human irrationalities, and to create or refine economic policy based on evidence. Complementing these, there are two elements — foundational and practical — to why the question of whether diversification in particular is an elementary, and perhaps intrinsic, behavioral trait is an important one to address. From a foundational perspective, an understanding of the development of diversification preferences may help us gain insights into behavioral diversification heuristics and biases in adults, and may thus yield insights into understanding where such widely documented human behavior is coming from. Indeed, many other behavioral heuristics, such as selfishness, cooperation and risk aversion, have been argued as being elementary and perhaps intrinsic to human nature. Moreover, diversifying behavior known as *bet-hedging* has been widely documented in other species (Hopper 1999, Olofsson, Ripa, and Jonzén 2009, Starrfelt and Kokko 2012, Rajon, Desouhant, Chevalier, Debias, and Menu 2014, Ackerman, Maner, and Carpenter 2016). We therefore ask whether the ability to choose diversification over concentration for the purpose of mitigating uncertainty is something that is universally present and hence an elementary intuition that exists at a very young age, or whether it only appears at adulthood. Studying diversification in children, whose cognitive and emotional development is still in progress, thus highly variable and unaffected by formal theoretic or financial schooling, offers great promise for a better understanding of diversification biases in the investment universe. In particular, what modern theory postulates as being an anomalous or irrational portfolio choice may have pre-wired developmental roots explaining where these tendencies are coming from. Furthermore, it can support a new theoretical foundation for the so far empirically focused investigation of diversification. Moreover, understanding how broadly any diversification related bias manifests itself may influence how one should incorporate them into more adequate models of individual decision making and portfolio choice models. In terms of practical impact, several factors may render this paper's insights valuable. First, empirical evidence shows that children and adolescents influence to a large extent many household decisions and that, over the past few decades, their purchasing power has increased substantially, at least in highly developed countries (McNeal 1992, Dauphin, El Lahga, Fortin, and Lacroix 2011). Second, now that the costs of entering the stock market have fallen, more individuals are investing in the market with no clear understanding of how to diversify or manage risk. Third, the worldwide trend toward defined contribution retirement savings plans (Benartzi and Thaler 2001, Benartzi and Thaler 2013), and the possibility of individual accounts in social security systems mean that individuals are more responsible for their own financial well-being in retirement. It is therefore natural to ask how well they are handling these tasks and understand the behavioral drivers that lead them to certain choices. In terms of concrete applications, the suggestion that some amount of our diversifying behavior has an elementary component may have implications for how one can treat these diversification tendencies. For example, if a diversification bias such as the naive diversification heuristic has deep developmental roots, this may lead us to believe that it will persist in a variety of settings, will be stable across time, ages and cultures, and may endure even in the face of repeated financial disciplining. This could constrain the potential for successful policy intervention, but could also support the idea of financial literacy training to non-professionals from a very young age, which is a popular ongoing debate (see for example Huston 2010, van Rooij, Lusardi, and Alessie 2011, Bucher-Koenen and Lusardi 2011, Brown and Graf 2013).

In this paper, we report on results of an experiment that tests whether children apply the diversification heuristic in a sequence of hypothetical choice questions and simple dice-rolling games. We studied 76 primary school children across the first six school grades. We described the experiment as a scientific research project that studies decision making in children and carried it out without revealing its purpose. The hypothetical choice questions test for whether children would diversify when faced with a number of different types of candy. They address the proverb that *variety is the spice of life*, the notion that decision makers diversify across consumption goods simply for the sake of attaining diversity. The purpose of the dice-rolling games is to replicate risky assets in a primitive portfolio choice problem and to test for whether children diversify in order to mitigate uncertainty. In its simplest form, an asset is represented by a die whose rolling outcome represents either a loss or a gain to the child. We study how children would allocate a number of coupons, which can be exchanged for candy later on, to different colours on various dice. A diversifying child would not allocate all of their coupons to one die outcome but would spread the risk across different outcomes. Because of the standard hypothesis in financial economics stating that risk averse investors would prefer to diversify, we also examine the children's risk attitudes and their relationship to diversification preferences.

This experiment is to our knowledge the first study of children's financial decision making in the context of diversification and portfolio choice. It is designed as a simple, unsophisticated elicitation of diversification in terms of familiar dice-rolling games, and hence requires no ability to forecast risky outcomes, no rigorous understanding of probability, and no familiarity with financial decision making. On the other hand, most of the experimental and empirical studies of diversification in adults are about violations of traditional paradigms, and do not address the intrinsic nature of diversification. Our results indicate that diversification preferences may have fundamental, developmental roots. Overall, we find that children do exhibit preferences for diversification, both for the sake of diversity across unknown consumption goods and for the purpose of mitigating risk and uncertainty when faced with a choice across risky gambles. The naive diversification heuristic, which implies an equal allocation across alternatives, is particularly evident in children's choices, but only when the underlying alternatives are equivalent or unknown. When there is a clear ranking of one alternative over another, children tend to apply a probability matching strategy and thus maximize (risk-adjusted) payoff. Moreover, unlike what traditional financial and economic theory stipulates, we find no significant relationship between risk aversion and diversification. This lack of correlation between risk aversion and diversification has previously been observed in experiments involving the Capital Asset Pricing Model (CAPM) (Bossaerts, Plott, and Zane 2007). However, when the risk-payoff profiles of gambles differ, there is a difference between risk averse and risk seeking children in their allocation.

Our findings provide the following two insights. First, diversification may be an elementary behavioral decision mechanism that did not necessarily and exclusively arise because of a sophisticated understanding of the optimal way to process information in a portfolio choice problem; rather, preference for diversification may be a fundamental pre-wired heuristic that helps us make decisions about standalone versus combined choices. Second, despite the fact our experiment participants were never exposed to formal financial literacy training, children as young as primary school age seem to act in a rational manner when making decisions on allocating wealth to risky gambles. These two insights may have implications for how one can treat, and perhaps prevent, portfolio choice anomalies in adults in practice.

The remainder of this paper is organized as follows. In Section 2, we explain the relevant background of the theory of diversification preferences and risk aversion, with a focus on the portfolio choice problem. Section 3 reviews relevant previous experiments investigating diversification, risk attitudes and decision making under uncertainty in adults and children. Section 4 explains our experimental design and procedure, and Section 5 discusses our results. We conclude in Section 6 by examining the implications of our findings.

2 Theory

The starting point of our analysis is traditional financial decision making, where an individual who chooses to diversify is roughly understood to prefer variety over similarity. We adopt the model-independent definition of Dekel (1989), according to which a preference relation $\succsim$ on a convex set of choices $\mathcal{X}$ exhibits *preference for diversification* if for any finite collection of choice alternatives $x_1, \ldots, x_n \in \mathcal{X}$ and weights $\alpha_1, \ldots, \alpha_n \in [0,1]$ satisfying $\sum_{i=1}^{n} \alpha_i = 1$, we have

$$x_1 \sim \cdots \sim x_n \Rightarrow \sum_{i=1}^{n} \alpha_i \, x_i \succsim x_j \quad \text{for all } j = 1, \ldots, n. \tag{1}$$

An individual will hence want to diversify among a collection of choice alternatives all of which are equivalently ranked. This model-independent notion of diversification corresponds exactly to that of convexity of preferences, which states that for any pair of choice alternatives $x, y \in \mathcal{X}$, $\alpha\, x + (1-\alpha)\, y \succsim y$, for all $\alpha \in [0,1]$, if $x \succsim y$. This represents the idea that averages are better than extremes, which roughly corresponds to the concept of diminishing marginal utility without requiring utility functions. Convex preferences with their associated convex indifference maps arise from quasi-concave utility functions, although these are not necessary for the analysis of preferences.

The most common example of diversification preferences is within the universe of asset markets, where an investor faces a choice amongst risky positions, such as equities, derivatives, or portfolios. Such risky positions are usually modeled as random variables on some state space Ω under a given objective reference probability $\mathbb{P}$. Diversification across two equivalently ranked risky assets x and y is then expressed by the state-wise convex combination $\alpha\, x(\omega) + (1-\alpha)\, y(\omega)$ for $\mathbb{P}$-almost all $\omega \in \Omega$ and $\alpha \in [0,1]$. In this context, preference for diversification means that an investor would prefer to allocate a fraction α to asset x and a fraction $1-\alpha$ to asset y rather than fully invest in either one of the assets.

There are broadly two hypotheses for why individuals exhibit preference for diversification. The first relates to choice among consumption goods, where decision makers tend to diversify because they simply prefer "variety for the sake of variety" (Middleton 1987). There are three main reasons proposed in the literature for why consumers prefer variety (Kahn 1995): (i) for satiation and stimulation; (ii) as a result of external factors such as price changes; and (iii) because of preference uncertainty. Experimental evidence also shows that variety-seeking often leads consumers to choose a larger number of alternatives even when some of the alternatives chosen are not among the most preferred (Ratner, Kahn, and Kahneman 1999). The second hypothesis for the purpose of diversifying is summarized by the proverb of not putting all of one's eggs into one basket. This stipulates that decision makers introduce variety to a set of alternatives whose outcomes are uncertain. Diversifying here is thus a strategy for risk mitigation. Indeed, in expected utility theory (EUT) of von Neumann and Morgenstern (1944), preference for diversification is equivalent to the concavity of the utility function, which in turn is equivalent to risk aversion (see De Giorgi and Mahmoud 2016). Therefore, under EUT, diversification is preferred because it leads to a reduction of "risk" or "uncertainty".

The same reasoning applies to Markowitz's (1952) mean-variance preferences. Consider the problem of investing in two risky assets with random payoffs x and y, with expected returns μ_x and μ_y, volatilities $\sigma_x > 0$ and $\sigma_y > 0$, respectively, and correlation $\rho \neq 1$. The diversifying decision maker invests α of his wealth in asset x and the remaining $1-\alpha$ in asset y, implying an overall portfolio payoff of $z = \alpha\, x + (1-\alpha)\, y$. The goal of mean-variance decision makers is to optimize the tradeoff between the portfolio's volatility and its expected return, which is formalized as the following optimization problem:

$$\max_{\alpha} \left(\mu_z - \frac{\gamma}{2}\,\sigma_z^2\right) \tag{2}$$

where $\mu_z = \alpha\, \mu_x + (1-\alpha)\, \mu_y$, $\sigma_z^2 = \alpha^2\, \sigma_x^2 + 2\, \alpha\, (1-\alpha)\, \rho\, \sigma_x\, \sigma_y + (1-\alpha)^2\, \sigma_y^2$, and $\gamma > 0$ is the coefficient of risk (volatility) aversion. Solving Problem 2, the optimal weight of asset x corresponds to

$$\alpha^\star = \frac{(\mu_x - \mu_y) - \frac{\gamma}{2}\,(2\,\rho\,\sigma_x\,\sigma_y - 2\,\sigma_y^2)}{\gamma\,(\sigma_x^2 - 2\,\rho\,\sigma_x\,\sigma_y + \sigma_y^2)}.$$

This formula shows that $\alpha^\star > 0$ if and only if $\frac{d}{d\alpha}\Big|_{\alpha=0} \left(\mu_z - \frac{\gamma}{2}\,\sigma_z^2\right) > 0$, which in turn implies that the mean-variance decision maker prefers to diversify when either risk decreases or when additional risk is fully compensated by a larger expected return (for example when $\mu_x > \mu_y$ and $\rho \leq 0$, independently from σ_x and σ_y). Consequently, among two portfolios with the same expected return, the mean-variance investor prefers diversification if and only if the portfolio's overall risk is lowered.

Three special cases are worth emphasizing in this context. First, when x and y are equally ranked by the mean-variance decision maker, i.e., $\mu_x - \frac{\gamma}{2}\,\sigma_x^2 = \mu_y - \frac{\gamma}{2}\,\sigma_y^2$, then

$$\alpha^\star = 1 - \alpha^\star = \frac{1}{2}$$

independently from the coefficient of risk aversion γ and the correlation ρ. This means that if two assets are equally preferred, they are equally weighted regardless of their correlation, a fact first proven by Samuelson (1967). Second, when $\rho = -1$ and thus x and y have perfect negative linear correlation, then

$$\alpha^\star = \frac{\mu_x - \mu_y}{\gamma\,(\sigma_x + \sigma_y)^2} + \frac{1}{1 + \frac{\sigma_x}{\sigma_y}}.$$

The case of perfect negative correlation between two assets is particularly interesting, because it offers the highest risk diversification potential to mean-variance decision makers. Indeed, when x and y are perfectly negatively correlated, then $y = a\,x + b$ almost surely for some $a < 0$ and $b \in \mathbb{R}$. Therefore, the portfolio payoff is

$$z = \alpha\,x + (1-\alpha)\,y = (\alpha\,(1-a) + a)\,x + (1-\alpha)\,b,$$

and with $\alpha = \frac{a}{a-1}$, we have

$$z = \frac{b}{1-a}.$$

This means that risk has been fully diversified away. In our experiment, we mainly impose $\rho = -1$ and $\sigma_x = \sigma_y$, implying $\alpha^\star \geq \frac{1}{2}$ when $\mu_x \geq \mu_y$, and $\alpha^\star \searrow \frac{1}{2}$ when $\gamma \nearrow \infty$. In other words, if the individual payoffs of two assets have perfect negative correlation and identical volatilities, the mean-variance investor aims to achieve a higher portfolio expected payoff by investing a higher proportion in the asset with higher expected payoff. However, as volatility aversion increases, the optimal strategy converges to $\alpha^\star = \frac{1}{2}$, which fully diversifies risk away. The third special case deals with zero correlation ($\rho = 0$). Here, x and y are linearly independent, and then

$$\alpha^\star = \frac{\mu_x - \mu_y}{\gamma\,(\sigma_x^2 + \sigma_y^2)} + \frac{1}{1 + \left(\frac{\sigma_x}{\sigma_y}\right)^2}.$$

Again, if $\rho = 0$, $\sigma_x = \sigma_y$, then $\alpha^\star \geq \frac{1}{2}$ for $\mu_x \geq \mu_y$, and $\alpha^\star \searrow \frac{1}{2}$ when $\gamma \nearrow \infty$ for $\mu_x \geq \mu_y$.

Finally this paper also addresses the naive diversification paradigm, one of the most widely applied simple rules of choice. It stipulates that a decision maker allocates equal weights, i.e., $\alpha_i = \alpha_j$ for all i, j, among a given choice set, independent of the individual characteristics of the underlying choice alternatives. In the context of portfolio selection, naive diversification is often referred to as the *equal-weighted* or $1/n$ diversification strategy and has been shown to deliver superior risk-adjusted performance relative to optimised portfolios (DeMiguel, Garlappi, and Uppal 2007). Empirical evidence shows that in the real world people typically do not always diversify according to EUT preferences or mean-variance preferences. By contrast, they apply the naive diversification paradigm. Naive diversification preferences have been studied from a theoretic perspective in De Giorgi and Mahmoud (2017). Here, naive diversification is framed as a preference for equality over inequality, which has a utility representation via Schur-concave functions (Schur 1923), capturing the idea of being inequality averse on top of being risk averse. The notion of permutation invariance lies at the core of the naive diversification axiom. Permutation invariance represents the attitude that the underlying characteristics of the individual choices are irrelevant in the decision making process, which formally means that the decision maker is indifferent towards a permutation of the components $\alpha_1, \dots, \alpha_n$ of the choice vectors. Naive diversification preferences could also arise in the case that a decision maker does not have any reason to favour one choice alternative to another. For example, as discussed above, mean-variance decision makers assign equal weights to assets that are equivalently ranked. One of the earliest related hypotheses is the *principle of insufficient reason*, also called the *principle of indifference*. It is generally attributed to Bernoulli (1738) and invoked by Bayes (1763) in his development of the binomial theorem. The principle states that in situations where there is no logical or empirical reason to favor any one of a set of mutually exclusive choices over any other, one should assign them all equal probability. In Bayesian probability, this is the simplest non-informative prior. Overall, the naive diversification paradigm, when applied to alternatives that are not equivalent, continues to be viewed as a simple and practical rule of thumb with no economic foundation guaranteeing its optimality. It inherently implies a lack of sophistication and is widely viewed as an anomaly linked to irrational behavior. The underlying rationale for naively diversifying across a set of assets is generally conjectured to be lack of sophistication, complexity reduction, correlation neglect, limited financial literacy, probability neglect, effects of cognitive load and attentional biases. Under these behavioral and cognitive heuristics, the decision maker is essentially simplifying the problem by assuming that the underlying alternatives are all equivalent, and thus they are being assigned equal probabilities.

3 Related experiments

Experimental studies on diversification in the past have focused on naive diversification viewed as an "investment anomaly." Some of the first academic demonstrations of naive diversification as a decision making paradigm were made by Simonson (1990) in marketing in the context of consumption decisions by individuals, and by Read and Loewenstein (1995) in the context of experimental psychology. In the context of economic and financial decision making, experimental evidence suggests behavior which is consistent with naive diversification. For instance, Benartzi and Thaler (2001) study whether the effect manifests itself among individuals choosing their personal defined contribution saving plans. Their experimental evidence suggests that some people spread their contributions evenly across the investment options irrespective of the particular mix of options. The authors point out that while naive diversification can produce a "reasonable portfolio", it affects the resulting asset allocation and can be costly. In particular, people might choose a portfolio that is not on the efficient frontier, or they might pick the wrong point along the frontier. Subsequently, Huberman and Jiang (2006) find that participants tend to invest in only a small number of the funds offered to them, and that they tend to allocate their contributions evenly across the funds that they use, with this tendency weakening with the number of funds used. More recently, Baltussen and Post (2011) find strong evidence for what they coin as *irrational* diversification. Their subjects follow a conditional naive diversification heuristic as they exclude assets with an unattractive marginal distribution and divide the available funds equally between the remaining, attractive assets. This strategy is applied even if it leads to allocations that are dominated in terms of first-order stochastic dominance – hence the term irrational. Irrationality has been since then frequently used to describe naive diversification behavior. In Fernandes (2013), the naive diversification bias of Benartzi and Thaler (2001) was replicated across different samples using a within-participant manipulation of portfolio options. It was found that the more investors use intuitive judgments, the more likely they are to display the naive diversification bias. In the context of portfolio construction, naive diversification has enjoyed a revival during recent years because of its simplicity and the growing empirical evidence suggesting superior performance compared to traditional diversification schemes (Lessard 1976, Roll 1981, Ohlson and Rosenberg 1982, Breen, Glosten, and Jagannathan 1989, Grinblatt and Titman 1989, Korajczyk and Sadka 2004, Hamza, Kortas, L'Her, and Roberge 2007, Pae and Sabbaghi 2010, DeMiguel, Garlappi, and Uppal 2007, Duchin and Levy 2009). This rather surprising superiority is often explained by the fact that undervalued low-risk assets receive more weight in the naive allocation.

The vast majority of experimental research in diversification and decision making has been conducted with adults rather than children. Much less is yet known about how diversification preferences develop with age, in particular before adults enter working life and face crucial decisions regarding for example their retirement investment. In the context of economic decision making in general, pioneering work of Harbaugh, Krause, and Berry (2001) investigates rationality of children's revealed preferences, children's risk aversion and risk attitudes (Harbaugh, Krause, and Berry 2001), and their trust and trust-worthiness (Harbaugh, Krause, and Vesterlund 2003). Other-regarding preferences, selfishness and cooperation have also been studied extensively in experiments on children (see for example Murnighan and Saxon 1998, Benenson, Pascoe, and Radmore 2007, Sutter and Kocher 2007, Fehr, Bernhard, and Rockenbach 2008, Fehr, Glätzle-Rützler, and Sutter 2013), where the overall evidence suggests that humans become less selfish as they grow older.

In another strand of academic research, experiments that aim at capturing children's cognitive capabilities of understanding risk, monetary rewards, uncertainty and probabilities have been carried out extensively in the child development and cognitive psychology literature, lead by seminal works of Marks (1951) and Slovic (1966), who study children's decision making when faced with risky choices.

In particular, early experimental work indicates that children exhibit a mature understanding of probabilities only in the stage of formal operations (Piaget and Inhelder 1975). More recent work confirms that children as young as 5 or 6 years old show a firm understanding of probabilities and expected value (Schlottmann 2001, Tsakiridou and Vavyla 2015) and that they are able to evaluate gains and losses in gambles (Levin and Hart 2003). These studies contribute to the growing evidence on children's overall intuitive reasoning competence and their relative probabilistic sophistication.

Based on this evidence taken collectively, we thus contend that models of behavior in a financial economics context can work about as well for children as they do for adults and can be experimentally tested in a similar manner. Financial diversification models in particular assume rational individuals with unlimited wants but limited resources and an understanding of the notion of risk. There is little argument about the extent of children's wants or resources, and the extensive literature dedicated to studying children's cognitive ability indicates that they are able to make rational decisions when faced with uncertainty. This supports the idea of an experiment eliciting children's diversification preferences among risky gambles, whose outcomes are probabilistic yet with real payoffs, such as in the form of popular consumption goods. Our precise experimental design replicating a portfolio choice problem is described next.

4 Experimental design

4.1 Design

Participants engaged in two parts with increasing complexity. Given the young audience, the experiment's two parts were not randomized, as the simpler questions of Part 1 were designed as a reasonable start for all participants.

Part 1. Part 1 consisted of four questions (Q1–Q4). In each question, we asked the participants to choose between different hypothetical bags of (unknown) types of candies. The purpose of these questions is to understand whether children abide by the diversification paradigm in the simplest choice scenario not involving any probabilities or explicit gambles. An element of uncertainty is added by not revealing the specific types of candies. In Q1, the children were asked to choose between two hypothetical bags, each containing four candies, where the candies in the first bag were all of the same type, and the candies in the second bag contained two different types, two candies of each type. Letting n denote the number of different types of candy in each choice, Q1 hence looked into whether diversity (number of alternatives $n = 2$) is preferred over similarity ($n = 1$). Question Q2 generalizes question Q1 by varying n between 1 and 4 and the allocation α to each candy type between 25% and 100%. Here, the choice is between four bags of several unknown candies: the first bag contained four candies of the same type ($n = 1$ and $\alpha = 100\%$); the second bag contained two different types of candies, two of each type ($n = 2$, $\alpha_1 = 50\%$ and $\alpha_2 = 50\%$); the third bag again contained two different types of candies but three of one type and one of a second type ($n = 2$, $\alpha_1 = 75\%$ and $\alpha_2 = 25\%$); and the fourth bag contained four candies, all of different types (i.e., $n = 4$, $\alpha_i = 25\%$ for $i = 1, \ldots, 4$). The next two questions, Q3 and Q4, asked the children to allocate ten hypothetical coupons to two different types of candies, where in Q3 both candy types were unknown, and in Q4 one type of candy was unknown and the second type was their favourite candy type. Here, the allocation problem is more explicit. Our goal in Q3 and Q4 was to elicit the weights assigned to each candy type and to explore whether information availability affects the chosen allocation. An overview of the four questions making up Part 1 of the experiment can be found in Table 1.

Table 1: Questions in Part 1 of the experiment. The table summarizes the four questions Q1–Q4 asked to participants in the first part of the experiment. Questions Q1 and Q2 were choice tasks, where participants had to choose between 2 and 4 different choice alternatives, respectively. Questions Q3 and Q4 were elementary portfolio allocation problems, where participants were asked to allocate 10 hypothetical coupons between two different choice alternatives.

Question	Problem	Choice alternatives
Q1	choice	A: 4 candies, all of type 1
	between	B: 4 candies, two of type 1 and two of type 2
Q2	choice	A: 4 candies, all of type 1
	between	B: 4 candies, two of type 1 and two of type 2
		C: 4 candies, one of type 1, and three of type 2
		D: 4 candies, one of type 1, one of type 2, one of type 3, and one of type 4
Q3	allocation	A: candy type 1
	between	B: candy type 2
Q4	allocation	A: candy type 1
	between	B: favourite candy type

Part 2. The second part of the experiment involved a sequence of gambles, which we refer to as games G1–G7. These games aim to replicate a portfolio choice problem under risk and uncertainty and to elicit children's risk attitudes and diversification preferences. To implement gambles for young children, a variety of simple instruments have been suggested and used in the literature, such as the spinner wheel task (Harbaugh, Krause, and Vesterlund 2001, Huber and Huber 1987, Reyna and Ellis 1994), drawing cards from a deck (Marks 1951), or the use of safe versus disaster switches

(Slovic 1966). We have chosen to implement gambles in terms of rolling dice for two main reasons. First, the majority of children at primary school age (6 to 12 years old) have been previously exposed to board or card games involving dice, and hence the concept of an uncertain outcome based on the result of rolling a die was familiar to them. Second, in terms of experimental implementation, generating different yet simple payoff distributions with specific correlation structures using dice did not require any sophisticated infrastructure nor the necessity to instruct participants on how to understand them.

The goal of the first game G1 was to allow children to familiarize themselves with the type of dice-rolling games in the remainder of the experiment. In G1, the children were asked to choose between either receiving a coupon and keeping it for sure (to be exchanged for candy later on), or to play a game, which involved picking a colour (blue or red) and rolling a fair die with three sides coloured in blue and three sides coloured in red. If the game was played and the die landed on the colour that was picked, the participant received two coupons in return, otherwise he/she received nothing. Because the expected payoffs of both playing and not playing the game are identical, risk averse children would, in theory, keep the coupon and not play the game, while risk seeking children would play the game instead. As G1 was designed as a "warm-up" round, it was not rewarded in the experiment and will not be evaluated in this paper.

The next sequence of four games (G2–G5) were designed to elicit children's diversification preferences. In each game, we asked the children to allocate 10 coupons to the colours red or blue on a 6-sided die whose sides were each coloured in either red or blue. In G2, the die had four blue and two red sides; in G3 we used a fair die with three sides in each colour; in G4 we did not tell the children the colour distribution on the die; and in G5 we used an unfair die with five blue sides and one red side. We then rolled the die and the children received the amount of coupons corresponding to their chosen allocation to the winning colour. These games replicate an allocation problem between two risky assets with perfect negative correlation and identical volatilities, and we varied the expected payoffs of the two assets by using different dice. As discussed in Section 2, in games G2 and G5, the mean-variance decision maker will always allocate more coupons to the asset with higher expected payoff. In game G3, the naive diversification strategy is always optimal for the mean-variance decision maker. In game G4, participants faced uncertainty about the payoff distribution. Assuming the prior that two assets should be equally ranked, the naive diversification strategy would be optimal for the mean-variance decision maker.

The next game (G6) was designed to elicit children's risk attitudes. The children were given the option of choosing how many of the 10 coupons they would like to keep for sure and how many they would like to allocate to the colours red or blue on a fair 6-sided die with three sides in each colour. They were rewarded twice the amount of coupons allocated to the winning colour. Because the expected payoff is independent from the chosen allocation, risk aversion is equivalent to choosing a risk-free allocation. This can be achieved by keeping some or all coupons for sure and equally splitting the rest between the two colours.

Finally, the problem of allocating coupons to two equally distributed risky gambles with zero correlation is addressed in G7. Here, the children were asked to assign 10 coupons to two different fair dice, each with three blue and three red sides. Both dice were rolled simultaneously, and the allocated coupons were paid off for each die when the colour red appeared, otherwise the participant received nothing. As discussed in Section 2, in game G7 the naive diversification strategy is always optimal for the mean-variance decision maker.

An overview of the games in Part 2 of the experiment can be found in Table 2.

Table 2: Games in part 2 of the experiment. The table summarizes the seven games G1–G7 played with the participants in the second part of the experiment. Game G1 was a warm-up choice task, while games G2-G7 were portfolio allocation problems with risky (G2, G3, G5, G6, G7) or uncertain (G4) payoffs. The last columns in the table report the correlations between the choice alternatives, which were ether -1 or 0.

Game	Problem	Choice alternatives	Correlation ρ
G1	choice between	$A1$: 1 with 100% probability $B1$: 2 with 50% probability and 0 with 50% probability	
G2	allocation between	$A2$: 1 with 66.66% probability and 0 with 33.34% probability $B2$: 1 with 33.34% probability and 0 with 66.66% probability	$\rho(A2, B2) = -1$
G3	allocation between	$A3$: 1 with 50% probability and 0 with 50% probability $B3$: 1 with 50% probability and 0 with 50% probability	$\rho(A3, B3) = -1$
G4	allocation between	$A4$: 1 or 0 with unknown probabilities $B4$: 1 or 0 with unknown probabilities	$\rho(A4, B4) = -1$
G5	allocation between	$A5$: 1 with 83.33% probability and 0 with 16.67% probability $B5$: 1 with 16.67% probability and 0 with 83.33% probability	$\rho(A5, B5) = -1$
G6	allocation between	$A6$: 1 with 100% probability $B6$: 2 with 50% probability and 0 with 50% probability $C6$: 2 with 50% probability and 0 with 50% probability	$\rho(A6, B6) = 0$ $\rho(A6, C6) = 0$ $\rho(B6, C6) = -1$
G7	allocation between	$A7$: 1 with 50% probability and 0 with 50% probability $B7$: 1 with 50% probability and 0 with 50% probability	$\rho(A7, B7) = 0$

4.2 Motivating questions and hypotheses

Our experiments were designed to address the following three questions.

Is variety preferred to similarity? Variety is the proverbial spice of life. Preference for variety is well-documented and considered a "virtually universal law of human (and animal) preferences" (Middleton 1987). Given the vast empirical evidence on preference for variety, especially when faced with choice among consumption goods, Part 1 of the experiment consisting of hypothetical choices addresses the question of whether children prefer variety in consumption over similarity. In questions Q1 and Q2, which ask children to choose between bags containing different types of unknown candies, we hypothesize that the majority of participants prefer bags with larger variety of candies compared to bags with lower variety of candies. Letting p_B and p_D denote the percentage of children choosing the two variety maximizing alternatives B and D in questions Q1 and Q2, respectively (see Table 1), we thus test the following two hypotheses:

H1: $p_B > 0.5$ in Q1

H2: $p_D > 0.5$ in Q2

Similarly, in questions Q3 and Q4, which ask the children to allocate 10 coupons to two different types of candy, we hypothesize that the majority of children allocate a strictly positive amount of coupons to each available option, even when one of these alternatives is described as their favourite type of candy. Letting α_A denote the percentage of coupons allocated to option A in questions Q3 and Q4 (see Table 1), we therefore test the following hypothesis:

H3: $\alpha_A > 0$ and $1 - \alpha_A > 0$ in Q3 and Q4

Is there a relationship between diversification and risk aversion? As discussed in Section 2, under EUT, preference for diversification is equivalent to risk aversion. However, this equivalence fails to hold in other models. To our knowledge, the relationship between risk attitude and diversification has not been investigated empirically or experimentally before. Moreover, in games G2 and G5, where the requested colour allocation is to unfair dice, optimal mean-variance allocations monotonically converge to equal weights when risk aversion increases. Based on the idea that diversifying behavior is an intrinsic trait, we contend that diversification is a general model-independent phenomenon and can be observed regardless of the decision maker's risk attitude. In particular, when the underlying alternatives are equivalent or unknown, as is the case in games G3, G4 and G7, children's diversification behaviour should be comparable among risk attitudes. On the other hand, following the relationship between risk aversion and diversification underlying EUT and mean-variance portfolio choice, we test whether children's diversification behaviour differs in games G2 and G5 depending on their risk attitudes. Here, we test whether risk seekers allocate a higher proportion to the choice alternative with higher expected return, thus ending up with riskier portfolios compared to risk averters. Let D denote a measure of dispersion of participants' allocations. This measure assigns nonnegative real numbers to different allocations, with its minimum equal to zero if all allocation weights are equal and with increasing values as the allocations become more diverse. Typical examples of such measures in the context of asset allocation are the Herfindahl-Hirschman Index (HHI) (Hirschman 1964) and the Gini coefficient (Gini 1921). We then test the following two hypotheses:

H4: $D_{averter} = D_{seeker}$ in games G3, G4, G7

H5: $D_{averter} < D_{seeker}$ in games G2 and G5

Are children always naive diversifiers? Given the view that the naive diversification paradigm is a simple intuitive rule of thumb, our final question asks whether children are naive diversifiers and, if not, we ask what might drive their chosen allocation. Recall that mean-variance decision makers apply naive diversification when the available choice alternatives have similar characteristics. Moreover, the principle of insufficient reason implies that naive diversification is used when no information on available choice alternatives is given to decision makers. In this case, naive diversification can be viewed as a consequence of the noninformative prior that available options have similar characteristics. Therefore, we hypothesize that naive diversification is observed in games G3, G4, and G7, where the alternatives are either equivalent or unknown. Letting α_{Ai} denote the percentage of coupons allocated to option Ai, for $i = 2, 3, 4, 5, 7$ in games Gi, respectively, we thus test the following hypothesis:

H6: $\alpha_{Ai} = 50\%$ for $i = 3, 4, 7$

Whether or not children apply the naive diversification heuristic even when faced with alternatives that are not equivalent in terms of their risk/payoff profile, is tested in the final hypothesis $H7$:

H7: $\alpha_{Ai} > 50\%$ for $i = 2, 5$

Hypothesis $H7$ essentially tests whether the chosen allocations depart from naive diversification in the two games $G2$ and $G5$, where the choice alternative $A2$ (respectively $A5$) dominates choice alternative $B2$ (respectively $B5$). Given the simple design of the games in terms of coloured dice and the evidence that children, even as young as kindergarten age, exhibit a level of probabilistic sophistication

(Schlottmann 2001), it seems plausible to expect children to deviate from naive diversification and assign more coupons to the die colour that has a higher chance of winning.

4.3 Subjects, reward structure and procedure

The experiment was conducted at the Swiss International School (SIS) Winterthur, a private bilingual (German/English) elementary school located in Winterthur, Switzerland. The experiment was approved by the principal headmaster of the school and was run during regular school hours. It was described to the children and supervising teachers as being part of a scientific research project that studies decision making in children, without revealing the details or purpose. In particular, any terminology relating to financial decisions, diversification, portfolios or investments were never used. All students attending school on the day of the experiment participated. There were a total of 76 participants, 43 female and 33 male children, spanning Grades 1 through 6 of the primary school years: 11 in Grade 1, 17 in Grade 2, 14 in Grade 3, 13 in Grade 4, 10 in Grade 5, and 11 in Grade 6. Both gender and grade were recorded for each child. We did not record individual ages, but children in Switzerland attending first grade are about 6 to 7 years old, and sixth graders are about 11 to 12 years old. The anonymity of the children was preserved by not asking them to write down their names. To be able to distribute rewards at the end of the experiment, we assigned a number to each child, which we asked them to record on their questionnaire packet.

Two experiment sessions were held to divide up the subject pool into Grades 1 through 3 followed by Grades 4 through 6. Dividing the participants this way simplified the experiment procedure, since the number of children attending each session was lower (42 and 34, respectively) and thus their supervision was practically simplified. Moreover, we expected the session with younger children of Grades 1-3 to last longer than for children in Grades 4-6. In each session, the participants were seated in a large hall, along with four supervising teachers, the school principal, and ourselves, who were the experiment leaders and instructors. Children were requested not to talk to their classmates during the experiment and to silently raise their hand in order to ask clarifying questions to the supervising teachers or the experiment leaders. The participants were given a stapled packet of papers, with each page containing one question or game. Each question and game was explained carefully one at a time. The participants then filled in their choices and the following question or game was read out and explained next. The outcome of the dice rolling games were only revealed to the children at the end of the experiment session. This helped avoid cheating incidents if the outcome of a game were to be displayed. To avoid satiation, the children were told that only one game (excluding G1) was going to

Table 3: Results questions Q1 and Q2. The tables displays the results of questions Q1 and Q2. Columns 2-7 report the percentage p_X (%) of participants choosing options $X = A, B$ and $X = A, B, C, D$ in questions Q1 and Q2, respectively. In question Q1, A has 4 candies, all of type 1, while B has 4 candies, two of type 1 and two of type 2. In question Q2, A has 4 candies, all of type 1, B has 4 candies, two of type 1 and two of type 2, C has 4 candies, one of type 1 and three of type 2, and D has 4 candies, one of type 1, one of type 2, one of type 3, and one of type 4.

	Q1		Q2			
	p_A	p_B	p_A	p_B	p_C	p_D
Overall	5.3	94.7	1.3	2.6	2.6	93.4
Female	4.7	95.3	2.3	0.0	0.0	97.7
Male	6.1	93.9	0.0	6.1	6.1	87.8
Grade 1	18.2	81.9	9.2	0.0	0.0	90.9
Grade 2	0.0	100.0	0.0	0.0	0.0	100.0
Grade 3	7.1	92.9	0.0	7.2	0.0	93.9
Grade 4	7.7	92.3	0.0	0.0	15.4	84.6
Grade 5	0.0	100.0	0.0	0.0	0.0	100.0
Grade 6	0.0	100.0	0.0	9.1	0.0	90.9

be rewarded by picking it at random using a dice numbered accordingly at the end of the experiment. The children who won some coupons could exchange them for the corresponding number of candies (m&m's or gummy bears) at the end of the experiment. Overall, the children were motivated by the idea of playing games that could lead to consuming these popular items.

5 Results and discussion

Variety over similarity. Table 3 reports participants' answers to questions Q1 and Q2, which required a choice between bags of unknown types of candies. Table 4 shows means and medians of the chosen allocations in questions Q3 and Q4, which asked children to assign 10 hypothetical coupons to two different types of candies, where both types were unknown in Q3 and one type was known to be their favourite candy in Q3. Table 4 also displays test results for the additional hypothesis that chosen allocations in Q3 and Q4 correspond to naive diversification.

The following conclusions arise from the results of these tables. There is overall a clear preference for variety over similarity. In choosing between bags with unknown types of candy, the large majority of children prefer the bag with the biggest variety (94.7% chose the bag with two different types of candies in Q1, supporting hypothesis H1, and 93.4% chose the bag with four different types of candies in Q2, thus supporting hypothesis H2). Similarly, the results of the allocation questions Q3 and Q4 show that variety is strongly preferred to similarity. In Q3 the median allocation to candy

Table 4: Results questions Q3 and Q4. The table summarizes the results of questions Q3 and Q4. Columns 2-3 report the percentage allocation α_A to option A in questions Q3 and Q4, respectively. In question Q3, there are two options, A and B, where option A is a candy of type 1, while option B is a candy of type 2. In question Q4, there are two options A and B, where A is a candy of type 1, while B is the favourite candy. We applied the two-sided Wilcoxon rank test to test the null hypothesis that the average allocation α_A to lottery A corresponds to 50% (naive diversification), against the alternative that it differs from this allocation. The p-values are reported with rejections at 5% confidence level indicated by *, at 1% confidence level indicated by **, and at 0.1% confidence level indicated by ***. We used the Bonferroni correction for multiple testing in order to compute p-values.

	Allocation α_A to A (%)	
	Q3	Q4
All (76)		
Mean	47.9	22.4
Median	50.0	20.0
p-value	(0.112)	(0.000)***
Female		
Mean	48.8	23.7
Median	50.0	20.0
p-value	(0.347)	(0.000)***
Male		
Mean	46.7	20.6
Median	50.0	20.0
p-value	(0.338)	(0.000)***
Grade 1		
Mean	47.3	17.3
Median	50.0	10.0
p-value	(1.000)	(0.043)*
Grade 2		
Mean	46.5	18.2
Median	50.0	25.0
p-value	(0.356)	(0.004)**
Grade 3		
Mean	47.1	23.6
Median	50.0	25.0
p-value	(1.000)	(0.009)**
Grade 4		
Mean	47.7	32.3
Median	50.0	30.0
p-value	(1.000)	(0.164)
Grade 5		
Mean	50.0	21.0
Median	50.0	20.0
p-value	(1.000)	(0.029)*
Grade 6		
Mean	50.0	21.8
Median	50.0	20.0
p-value	(1.000)	(0.021)*

type 1 was 50% and the hypothesis of equal weights among existing options cannot be rejected, thus supporting hypothesis H3. In question Q4, even though one of the two types of candy is described as being the favourite candy type, the median allocation to the unknown candy type is still 20%. By introducing a type of candy known to be their favourite, children clearly used this information in their allocation decisions, and thus the naive diversification hypothesis can be rejected. However, a majority of children (61 out of 76 participants) nevertheless prefer some degree of variety to similarity by not allocating all of their coupons to their favourite candy. All results are consistent across gender and age.

Note that this part of the experiment does not elicit the underlying drivers of the children's preference for variety. One rationale for this evident diversification preference is simply that variety is chosen for the sake of variety, which is consistent with research on variety across consumption goods. The results of question Q4, in particular, support this idea. A second interpretation arises based on the fact that the underlying alternatives are unknown, as the types of candy were not revealed. By adding this element of uncertainty, one may be inclined to conclude that children are regret averse or (perhaps subconsciously) diversifying to hedge against choosing too much of a candy type that they may end up not liking. However, there is no clear experimental evidence supporting one behavioral driver over another.

Diversification and risk aversion. To determine children's risk attitudes we used their allocations in game G6, which essentially represents an allocation task between a risk-free asset (keeping coupons) and a risky asset (playing the dice rolling game). Because in game G6 the expected payoff is independent from the allocation of the coupons, risk averse children are those choosing the risk-free payoff, while risk seekers are those taking on some level of risk. According to this classification, we divided participants into risk averters (46 children) and risk seekers (30 children) and analyzed their respective diversification behaviour. Note that, by design of the game, risk averters are those keeping some or all coupons for sure and equally splitting the remainder between the two colours on the fair die. Out of the 46 risk averse children, 20 kept all of their 10 coupons, whereas the remaining 26 kept some coupons and split the rest equally between blue and red. Technically, this means that the latter risk averse group diversify, whereas the former concentrate, with both groups achieving the same certain return of 10 coupons. Diversification may thus not have been applied for risk mitigation purposes, but rather for the sake of diversity, or "for the fun of it." Noteworthy, however, is the subtle idea that children may be risk averse regardless of their diversification preferences.

Tables 5 and 6 report our main results on the relation between diversification and risk attitudes.

The following observations emerge. First, Table 5 shows that only in games G2 and G5, in which unfair dice were used, we can reject the hypothesis that risk averters and risk seekers choose similar allocations (we exclude game G6 because this is used to classify children's risk attitudes). Indeed in these two games, risk seekers generally allocate more to the choice alternatives with higher expected payoffs than their risk averse counterparts (median differences are plus 10% and plus 20% in games G2 and G5, respectively) and thus end up with riskier portfolios. The results in Table 6 based on applying the Herfindahl-Hirschmann Index (HHI) and the Gini measure of inequality to the allocation weights confirm that in games G2 and G5 risk averters choose allocations with lower dispersion and hence closer to equality compared to risk seekers. This supports hypothesis H5. Overall, we conclude that whereas the large majority of children diversify to some extent in games G2 and G5, there is a significant relationship between their allocations to the alternative with higher expected payoff and their risk attitudes.

Next, we analyze the relationship between risk attitude and naive diversification in the three games in which the choice alternatives were either equivalent (games G3 and G7) or unknown (game G4). Table 5 shows that naive diversification cannot be rejected for both risk averters and risk seekers in these three games. We conclude that, when faced with equivalent or unknown alternatives, children allocate their coupons according to the naive diversification heuristic independent of their risk attitudes. This supports hypothesis H4.

We finally look into the role of probabilities in children's decision making and investigate whether these might be driving the differing allocations of risk averters and risk seekers. Our focus is now on games G2, G3 and G5, which are identical in design and differ only in the probabilities assigned to the two colours. In particular, we test whether children use probability matching, a decision strategy in which allocations are proportional to the probability of obtaining a strictly positive payoff in the corresponding choice alternatives. The probability matching strategy is of behavioral interest because, on one hand, it is frequently employed by human subjects in decision and classification studies (see for example Duda, Hart, and Stork 2001, Shanks, Tunney, and McCarthy 2002), and on the other hand, it would imply a level of probabilistic sophistication in the children. Probability matching implies allocations of 66.7%, 50%, and 83.3% to choices $A2$, $A3$ and $A5$ in games G2, G3, and G5, respectively. Table 7 displays the mean and median deviations from probability matched strategies in these three games. We can reject probability matching for risk averters in games G2 and G5, in which the die probabilities are not symmetric. Risk averse children are in fact generally closer in their allocations to naive diversification than to probability matching. The allocations of risk seekers, on

Table 5: Results for different risk attitudes and tests for naive diversification. The table shows mean and median allocations α_{Ai} to options Ai in games G2 to G7 for different risk attitudes, with risk attitude classification based on the outcome of game G6. The table also shows test results for the hypothesis that participants used naive diversification strategies in games G2, G3, G4, G5, G6, and G7. We applied one-side Wilcoxon rank test to test the null hypothesis that the mean allocation to lottery Ai in game Gi corresponds to 50% (naive diversification), against the alternative that it is strictly greater. The p-values are reported with rejections at 5% confidence level indicated by *, at 1% confidence level indicated by **, and at 0.1% confidence level indicated by ***. We used the Bonferroni correction for multiple testing in order to compute p-values.

	Allocation α_{Ai} to choice Ai (%)					
	G2	G3	G4	G5	G6	G7
Risk averse (46)						
Mean	59.3	53.5	53.9	68.7	71.3	47.8
Median	50.0	50.0	50.0	70.0	80.0	50.0
p-value	(0.001)***	(0.151)	(0.389)	(0.000)***	(0.000)***	(0.308)
Risk seeking (30)						
Mean	66.7	50.0	52.3	80.3	50.0	46.0
Median	60.0	50.0	50.0	90.0	50.0	50.0
p-value	(0.000)***	(1.000)	(0.472)	(0.000)**	(0.009)**	(0.321)
Mean difference	-7.3	3.5	1.6	-11.6	21.3	1.8
Median difference	-10.0	0.0	0.0	-20.0	30.0	0.0
p-value	(0.038)*	(0.237)	(0.418)	(0.014)**	-	(0.651)

the other hand, are very close to those of the corresponding probability matching strategies in games G2 and G5, suggesting that risk seeking children may have analyzed probabilities of outcome and used this information to match their allocations. Because in game G3, which used a fair die, probability matching coincides with naive diversification, it cannot be rejected for both risk averters and risk seekers, as here their allocations are close to naive diversification.

Naive diversification. So far, we have only analyzed the naive diversification heuristic in relation to risk attitude. We next address the question of whether children are applying this simple rule of thumb (independent of risk attitude) across all games. Table 8 reports the test results for hypotheses H6 (which conjectures that naive diversification is observed when choice alternatives are equivalent or unknown, as in G3, G4, and G7) and H7 (which tests whether children depart from naive diversification when choice alternatives are not equivalent, as in G2 and G5). We observe that naive diversification is rejected for games G2 and G5, conforming with our earlier results relating naive diversification to risk attitudes. This observation is also consistent across gender. However, for game G2, naive diversification cannot be rejected at the level of grades 1,2,4, and 5 (also because of small samples), while for game G5 the only exception is Grade 4. In games G3, G4, and G7, naive diversification

Table 6: Inequality among asset weights versus risk attitudes. The table reports results on the inequality among asset weights in games G2 to G7. As statistical dispersion measures of inequality, we use the Herfindahl-Hirschman Index and the Gini Index. The Herfindahl-Hirschman and the Gini indices for assets weights α_i for $i = 1, \to n$ correspond to $HHI(\alpha_1, \ldots, \alpha_n) = \frac{n \sum_{i=1}^{n} \alpha_i^2 - 1}{n-1}$ and $G(\alpha_1, \ldots, \alpha_n) = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} |x_i - x_j|}{2n}$, respectively. In both cases, naive diversification implies that HHI and G are identically zero. We also report theoretical values of HHI and G, when probability matching or mean-variance strategy with given levels or risk aversion are applied. We applied one-side Wilcoxon rank test to test the null hypothesis that HHI and G are equal under risk aversion and under risk seeking behaviour, against the alternative that HHI and G are higher under risk seeking behavior. The p-values are reported with rejections at 5% confidence level indicated by *, at 1% confidence level indicated by **, and at 0.1% confidence level indicated by ***.

	G2	G3	G4	G5	G6	G7
HHI						
Overall	0.20	0.11	0.09	0.44	0.49	0.09
Risk averse	0.17	0.10	0.05	0.33	0.57	0.05
Risk seeking	0.26	0.11	0.15	0.61	0.37	0.16
p-value	(0.020)*	(0.355)	(0.084)	(0.002)**	(0.886)	(0.166)
Prob. matched	0.11	0.00	-	0.44	-	-
Mean-variance optimal						
$\gamma = 2$	0.14	0.00	-	1.44	-	0.00
$\gamma = 3$	0.06	0.00	-	0.64	-	0.00
$\gamma = 10$	0.01	0.00	-	0.06	-	0.00
Gini						
Overall	0.14	0.08	0.07	0.27	0.61	0.06
Risk averse	0.12	0.07	0.05	0.22	0.68	0.04
Risk seeking	0.18	0.11	0.10	0.35	0.49	0.09
	(0.020)*	(0.355)	(0.084)	(0.002)**	0.993	(0.166)
Prob. matched	0.17	0.00	-	0.33	-	-
Mean-variance optimal						
$\gamma = 2$	0.07	0.00	-	0.77	-	0.00
$\gamma = 3$	0.03	0.00	-	0.32	-	0.00
$\gamma = 10$	0.01	0.00	-	0.03	-	0.00

Table 7: Test results for probability matching. The table shows mean and median deviations from probability matching (probability of payoff 1 in option Ai) of allocations α_{Ai} to options Ai in games G2, G3 and G5. The table also shows test results for the hypothesis that participants used probability matching in games G2, G3, and G5. We applied two-sided Wilcoxon rank test to test the null hypothesis that the average allocation to lottery Ai in game Gi corresponds to the probability of payoff 1 (probability matching), against the alternative that it differs. The p-values are reported with rejections at 5% confidence level indicated by *, at 1% confidence level indicated by **, and at 0.1% confidence level indicated by ***. We also report the results for different risk attitudes, which are defined based on game G6. We used the Bonferroni correction for multiple testing in order to compute p-values.

	Deviation of α_{Ai} from prob. matching (%)		
	G2	G3	G5
All			
Mean deviation	-4.4	2.1	-10.0
Median deviation	-11.7	0.0	-3.3
	(0.010)**	(0.151)	(0.004)**
Risk averse			
Mean deviation	-7.3	3.5	-14.6
Median deviation	-16.7	0.0	-13.3
	(0.010)**	(0.301)	(0.000)***
Risk seeking			
Mean deviation	-2.4	-0.6	-7.2
Median deviation	-6.7	0.0	-3.3
	(1.000)	(1.000)	(1.000)

cannot be rejected for all genders and grades.

Overall, the results indicate that naive diversification is generally chosen as an allocation strategy when alternatives are equivalent or unknown, thus supporting hypothesis H6. However, when one choice alternative is clearly superior, naive diversification is not applied. This is the case in game G5, where both available alternatives have the same volatility, but choice alternative $A5$ have higher expected payoffs.

These findings point to some level of probabilistic and financial sophistication, as children seem to be able to evaluate the underlying alternatives available to them in terms of their risk-payoff profile, and make a decision accordingly. So far, some experimental research on adults' portfolio choice has reached the conclusion that people are "naive" when it comes to asset allocation, as they equally weight their options regardless of what these options are. Clearly, the levels of sophistication of experiments involving choice between gambles in terms of simple dice-rolling games is significantly lower than those involving choice between real assets. However, we believe that the relative difficulty level when taking cognitive sophistication into account is comparable.

6 Concluding remarks

The notion of diversification is paramount, both as a choice heuristic and as a practical methodology for financial investment. However, the views of what constitutes reasonable diversification in the disciplines of finance and economic theory differ and tend to be exogenously given. Traditional diversification paradigms are consistently violated in practice, and anomalous diversifying behavior has been widely documented in empirical and experimental research.

Taking a behavioral viewpoint, we contend that diversification is an independent driving force of behavior that is not necessarily a consequence of knowledge of financial models, and — at least partly — an intrinsic preference with deep developmental roots. By testing whether young children, whose intuition plays a large role in their decision making and who have not (yet) received financial literacy or economic theory training, would indeed diversify when faced with a choice among several alternatives, we certainly do not prove our hypothesis, but we are contributing to the evidence supporting it. The central premise of this paper is that children do indeed possess an arguably refined sense for the potential upside of diversifying. Our findings suggest that (i) children diversify when faced with a choice of consumption goods; (ii) they are "naive" in their allocations only when the naive diversification is actually theoretically optimal; (iii) they are driven by a sophisticated understanding of probabilities when the given choice alternatives differ in their outcome probabilities; and (iv) that

Table 8: Results for games G1 to G7 and tests for naive diversification. The table shows mean and median allocations α_{Ai} to options Ai in games G2 to G7. The table also shows test results for the hypothesis that participants used naive diversification strategies in games G2 to G7. We applied one-side Wilcoxon rank test to test the null hypothesis that the mean allocation to lottery Ai in game Gi corresponds to 50% (naive diversification), against the alternative that it is strictly greater. The p-values are reported with rejections at 5% confidence level indicated by *, at 1% confidence level indicated by **, and at 0.1% confidence level indicated by ***. We also report theoretical values of α_{Ai}, when naive diversification, probability matching or mean-variance strategy with given levels or risk aversion are applied. We used the Bonferroni correction for multiple testing in order to compute p-values.

	Allocation α_{Ai} to choice Ai (%)					
	G2	G3	G4	G5	G6	G7
All (76)						
Mean	62.5	52.1	53.3	73.3	62.9	52.9
Median	55.0	50.0	50.0	80.0	65.0	50.0
p-value	(0.000)***	(0.151)	(0.026)*	(0.000)***	(0.000)**	(0.067)
Female (43)						
Mean	56.5	49.1	54.4	69.5	66.7	48.8
Median	50.0	50.0	50.0	70.0	70.0	50.0
p-value	(0.000)***	(1.000)	(0.370)	(0.000)***	(0.000)**	(0.588)
Male (33)						
Mean	69.7	56.1	51.8	78.2	57.9	44.8
Median	70.0	50.0	50.0	90.0	60.0	50.0
p-value	(0.000)***	(0.092)	(0.527)	(0.000)***	(0.002)**	(0.220)
Grade 1 (11)						
Mean	57.3	59.1	61.8	80.0	86.4	38.2
Median	50.0	50.0	50.0	100.0	90.0	50.0
p-value	(0.721)	(0.811)	(0.410)	(0.038)*	(0.010)**	(0.592)
Grade 2 (17)						
Mean	58.2	51.2	52.4	64.7	70.6	50.0
Median	50.0	50.0	50.0	60.0	100.0	50.0
	(0.170)	(1.000)	(0.796)	(0.089)*	(0.015)*	(1.000)
Grade 3 (14)						
Mean	75.7	57.9	54.3	92.9	44.3	45.7
Median	80.0	50.0	50.0	100.0	35.0	50.0
p-value	(0.018)*	(0.599)	(1.000)	(0.002)**	(1.000)	(1.000)
Grade 4 (13)						
Mean	59.2	47.7	46.9	56.9	60.8	48.5
Median	50.0	50.0	50.0	60.0	60.0	50.0
p-value	(0.175)	(1.000)	(1.000)	(1.000)	(0.012)*	(1.000)
Grade 5 (10)						
Mean	60.0	51.0	51.0	75.0	64.0	49.0
Median	50.0	50.0	50.0	80.0	55.0	50.0
p-value	(0.293)	(1.000)	(1.000)	(0.041)*	(0.017)*	(1.000)
Grade 6 (11)						
Mean	61.8	45.5	54.5	72.7	52.7	50.0
Median	60.0	50.0	50.0	80.0	50.0	50.0
p-value	(0.031)*	(1.000)	(1.000)	(0.024)*	(0.106)	(1.000)
Theory						
Naive	50.0	50.0	50.0	50.0	33.3	50.0
Prob. matched	66.7	50.0	-	83.3	-	-
Mean-variance optimal						
$\gamma = 2$	68.8	50.0	-	110.0	-	50.0
$\gamma = 3$	62.3	50.0	-	90.0	-	50.0
$\gamma = 10$	53.8	50.0	-	62.0	-	50.0

their risk attitudes affect their diversifying behavior only when one alternative is less risky than another. We conclude by asking where this seemingly rational behavior is coming from and what can be done with the knowledge of it.

Investigating the roots of decision making and behavioral preferences is an ongoing extensive effort of behavioral and financial economists, psychologists, neuroscientists and evolutionary biologists. One argument is that attitudes towards diversification may be the evolutionary product of natural selection. Tendencies towards diversifying across gambles may thus have been hard-wired by the evolutionary selection process. From an evolutionary biologist's perspective, this hypothesis may not come as a surprise, as the notion of diversification lies at the core of evolution and natural selection (Darwin 1859). Moreover, the types of preferences that psychologists and behavioral economists study, such as intertemporal choices, risk attitudes, selfishness and altruism, are also ubiquitous in biology and behavioral ecology. Indeed, the desirability of considering the biological formation of preferences has been strongly advocated by a number of economists, for example by Hirshleifer (1978). Another prominent supporter of this investigation is Robson (1996, 2001a, 2001b) (see also Robson and Samuelson 2009, Robson and Samuelson 2010), whose work promotes the idea that our attitudes to gambles over commodities were hard-wired by the evolutionary process and therefore continue to be exhibited today. Several other studies have yielded profound insights into the evolution of economic preferences, ranging from risk attitudes to entrpreneurial traits to altruism (see for example Karni and Schmeidler 1986, Hansson and Stuart 1990, Rogers 1994, Samuelson 2001, Curry 2001, Ok and Vega-Redondo 2001, Schlesinger 2003, Dekel, Ely, and Yilankaya 2007, Rayo and Becker 2007, Lakshminarayanan, Chen, and Santos 2011, Galor and Michalopoulos 2012). Moreover, diversifying behavior has received the attention of leading evolutionary biologists. Perhaps the most prominent is the article by Real (1980), who shows that diversified behaviors will prove advantageous for almost any expected evolutionary fitness. Other evolutionary writings touching upon diversification from a behavioral viewpoint include Frank and Slatkin (1990), who show that bet-hedging is always favoured when there are no associated costs, since it reduces the variance of a genotype's average reproductive success.

We thus argue that the extensive theoretical, experimental and empirical research dedicated to diversification in economics and finance is too narrow to fully account for the cognitive foundations of diversification preferences and their motivational causes. Considering the psychological, biological, evolutionary, and neuroscientific roots of diversifying strategies can illuminate investigations into the mechanisms supporting these behaviors. The results of our experiment support the idea that diversifying preferences are in some sense more elementary and fundamental to human behavior than modern theory suggests. That said, it is important to point out that our paper does not address the question of whether children's diversification preferences are innate rather than acquired. The idea that some of our behavioral characteristics are explained by our intrinsic nature, whilst others reflect the influence of the environment is an ancient one. An investigation of this distinction would require wide-ranging interdisciplinary research efforts and are beyond the scope of the experimental setup of this paper.

Even if no clear view of the innateness of diversification is given, the suggestion that some amount of our diversifying behavior has an intuitive, perhaps intrinsic component may have consequences for how one can treat these diversification tendencies in practice. There are three angles to potential implications. First, if a diversification bias such as the (naive) diversification heuristic has such an elemental basis, this may lead us to believe that it will persist in a variety of settings, will be stable across time, ages and cultures, and may endure even in the face of repeated financial disciplining. This may constrain the potential for successful policy intervention. Second, understanding how deeply any diversification related bias manifests itself may influence how financial economists should incorporate it into more adequate models of individual financial decision making. Third, given that our experiment indicates that children as young as primary school age display some level of gambling and financial sophistication, whereas extensive modern research documents irrational investment behavior in adults, one is inclined to ask why seemingly rational children develop into irrational adults when it comes to financial decision making. Even though preferences and external factors do change over time, our results indicate that children may be cognitively ready for financial literacy training in schools and for exposure to financial decision making from their parents from a very young age, and that any such formal training or exposure must remain consistent and appropriately structured all the way into adulthood. Controlled experiments tracking choices of different groups of children into adulthood based on the level of financial training received may provide more concrete insights and are the subject of future experimental research.

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